



## Soda Bottle Volcano—An Eruption Begins

**Overview:** Examine how gases provide the energy to create explosive volcanic eruptions by making comparisons to gases in a soda bottle and by conducting a carefully controlled “eruption” of baking soda/vinegar or soda water.

**Grade Level:** 5-8

**Learner Objectives** Students will...

- Understand the important role of gases in providing energy for explosive volcanic eruptions
- Understand how pressure affects gases
- Learn how gases influence the texture and appearance of volcanic rocks

**Setting:** outdoors or uncarpeted classroom with a tarp or plastic floor covering

**Timeframe:** 40 minutes

*“Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption”*  
(15 minutes)

*“Making Your Own Volcanic Eruption—Option 1 or Option 2”* (25 minutes)

**Materials:**

***“Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption”***

- Graphic *“The Role of Gas Bubbles in an Eruption”* (below)
- Teacher Page—Narrative *“What Starts an Eruption?”* (below)

***Making Your Own Volcanic Eruption—Option 2***

- Graphic *“Soda Bottle Volcano”* (below)
- 20 oz clear plastic soda bottle for each student
- Permanent ink marker pen
- 1 box baking soda
- 2 gallons vinegar
- 1 box tissue
- Spoon
- Paper towels
- Tarp or other plastic floor covering (optional)

**Vocabulary:** conduit, magma, magma chamber, exsolution, fumaroles, pumice, scoria, throat, volcanic ash,

**Skills:** demonstrating, inferring, observing, predicting

## **Benchmarks:**

### Science

1. The student understands and uses scientific concepts and principles.
    - 1.1 Use properties to identify, describe, and categorize substances, materials, and objects, and use characteristics to categorize living things
- Classify rocks and soils into groups based on their chemical and physical properties; describe the processes by which rocks and soils are formed

## **Teacher Background:**

### ***Water—The Surprisingly Essential Ingredient in Explosive Volcanic Eruptions***

Hot magma and water vapor seem incompatible. Yet, water vapor (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and lesser amounts of rarer gases take up as much as ten percent of the magma (by weight) that lies beneath some Cascade volcanoes. These gases are important because their expansion provides the energy that blasts magma to Earth's surface during an explosive volcanic eruption.

About 80 kilometers (50 miles) below the Earth's surface, water sweats off the subducted oceanic plate and promotes the formation of **magma**, which then rises into the Earth's crust. Water vapor and other gases, elements and minerals coexist as a mixture of molten or partially molten magma having a texture similar to hot oatmeal.

### ***A Magma Chamber is Like a Pot of Dessert Pudding***

Imagine magma as home-cooked pudding bubbling in a pot topped by a tight lid. Some of the ingredients in the pot combine as they cool; this is similar to the process of elements combining to form minerals. During this process, tiny bubbles of gas separate from their more solid surrounding neighbors. Since gases are lighter, they rise to the top of the pudding (or magma). As gases separate progressively from the pudding, bubbles rise, expand, and form a gas-rich layer at the top of the pot (or **magma chamber**).

### ***The Pot Boils Over***

The pressure of rising gases eventually forces the pot lid to vibrate. Puffs of steam break out between the pot and lid in the same way that volcanic gases escape the top of a magma chamber through cracks and openings in surrounding rocks.

The upward pressure of gases eventually exceeds the downward pressure exerted by the lid, and the pudding and gases pour over the side of the pot and onto the stovetop. This is the same concept as lava escaping across the slopes of an erupting volcano. Some of the pudding propels explosively out of the pot and splatters everywhere, similar to magma erupting from a volcano as rock fragments or ash.

### ***Gas Bubbles Determine the Texture of Volcanic Rock***

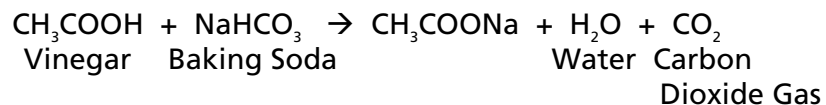
During an explosive volcanic eruption, gases escape into the atmosphere; however, some become trapped in the quickly cooling magma. The erupted magma, in the form of ash and lava, may contain bubble holes from the former presence of gases. The resulting rocks appear similar to foam from a bottle of soda. These rocks are called **pumice** and **scoria**. Sometimes the gas-rich magma erupts so explosively that it breaks into tiny fragments known as **volcanic ash**.

### ***How the Soda Bottle Experiment Is Like a Volcano***

The wide body and narrow neck of a soda bottle roughly resemble the shape of a magma chamber and the **conduit** or **throat** within a volcano. The pressurized soda water represents gas-rich magma that is under pressure from overlying rocks. Carbonated beverages get their fizz from the gas carbon dioxide. When the bottle is capped, carbon dioxide dissolves within the soda from the pressure exerted on it. It also occupies the void between the surface of the liquid and the cap. Shaking the bottle adds energy and causes gas in the soda water to separate, forming tiny bubbles throughout the liquid. Formation of the bubbles creates pressure inside the bottle. Quickly removing the cap releases this pressure, and the bubbles immediately expand. Forced up the narrow neck, the fluid and bubbles burst from the high-pressure environment of the bottle to the lower pressure of the atmosphere. Bubbles of water vapor and other gases within magma undergo a similar progression. They are initially dissolved in magma, then depressurization in the magma chamber frees the bubbles from the magma in a process called **exsolution**. The bubbles rise to the top of the magma chamber. Pressure from the gas bubbles propels both the magma and gas up the conduit. The gas bubbles now rapidly expand to thousands of times their original volume when escaping up the conduit to the top of the erupting volcano.

### ***How the Vinegar and Baking Soda Eruption is Unlike a Volcano***

Combining baking soda and vinegar causes a chemical reaction that quickly produces carbon dioxide bubbles:



This demonstration differs from the processes within real volcanoes, because the gases that cause explosive eruptions do not result from sudden chemical reactions. In the soda water and baking soda/vinegar experiments, carbon dioxide acts as the main gas driving the explosion. In most volcanic eruptions, water is the principal gas driving an explosive eruption and not carbon dioxide.

## **Procedure:**

### **Human Molecules—Studying the Role of Gas Bubbles in an Explosive Eruption**

Explore how gas molecules respond to pressure using an illustration and classroom demonstration.

1. Demonstrate how gas reacts to different pressure conditions. Divide the class into two groups. One group will act as “rock walls” and the other group will act as “gas molecules.” The gas molecules should always be in random motion.
2. Instruct the “rock walls” to form a tight circle around five of the “gas molecules.” Further instruct students (walls) not to change size of circle once formed.
3. Ask the five students (gas molecules) in the center of the circle to move randomly from one side of the “rock walls” to the other. They should have a difficult time doing this in such a tight space.
4. Add one student at a time from the “gas molecules” group to the inside of the circle until there are no more students (gas molecules) left. Students should have a hard time squeezing into the circle if the “rock walls” circle has not changed its size.
5. Tell everyone to “Freeze.”
6. Explain to the students that they have just demonstrated what happens in a magma chamber. Gases rise out of the magma and accumulate at the top of the chamber. As more gases accumulate, the pressure increases. Eventually the pressure of the gas exceeds the pressure of surrounding rock, so the gases must escape up the magma conduit.
7. Instruct the “rock walls” to enlarge the circle while the “gas molecules” remain in place.
8. Tell the “gas molecules” to mingle so that they move throughout the entire space. This is what happens when pressure is decreased; gases expand to fill up space.
9. Instruct two people in the “rock wall” to open a hole in the circle. This allows the “gas molecules” to escape rapidly, as in a volcanic eruption.

### **Making Your Own Volcanic Eruption**

Examine the role of gas in explosive volcanic eruptions by using a baking soda/vinegar mixture in a bottle. This activity can be done as a demonstration or in small student groups.

#### **Teacher Tips**

This activity can be messy, so do the experiment outside or in an easy-to-clean area.

#### ***Vinegar and Baking Soda Eruption***

1. Explain to students that they will be making baking soda/vinegar volcanoes. The baking soda reacts with vinegar to form carbon dioxide gas. Carbon dioxide, sulfur dioxide, and water vapor are common volcanic gases. Gases building up in the magma chamber provide the main trigger for volcanic eruptions.
2. Divide the class into groups of three or four.
3. Give each group an empty 20 ounce soda bottle. Using the “*Soda Bottle Volcano*” graphic as a model, have students draw a volcano on the empty soda bottle showing the magma conduit (throat), magma chamber, and surrounding rocks. Draw circles to illustrate bubbles that enlarge as they rise because of reduction of pressure.
4. Preferably in an outdoor setting, instruct students to prepare their makeshift volcano by pouring vinegar into the bottle to a depth of about 5 cm (two inches).

5. Each group should spoon one teaspoon of baking soda onto a thin piece of tissue. Gather the sides of the tissue and twist together to form a small bundle. Students **SHOULD NOT** push the baking soda bundle into the bottle until instructed to do so.
6. Before students activate the chemical reaction, inform them to make some observation during the experiment. Each group should look, listen, and feel for an increase in pressure within the bottle. They should watch the gas bubbles and note any increase or decrease in size. Additionally, they should keep an eye on the volume of gas bubbles produced during the remainder of the experiment.
7. Keeping the bottle pointed **AWAY** from viewers, students push the baking soda bundle into the bottle of vinegar. They should immediately place a hand over the top of the bottle and try not to let any gas escape. They should feel the pressure build and hear the escaping gases make hissing sounds similar to what you would hear near a real volcanic vent.
8. Instruct students to shake the bottle for 10-20 seconds with their hand firmly over the opening of the bottle. The gases inside the bottle will dramatically expand and propel a foamy froth into the air and down the sides of the bottle.
9. How did the students' results compare to that of a real volcanic eruption? Did the pressure increase? How do they know? How was covering the top of the soda bottle similar to a closed magma conduit? What happened to the size and quantity of the gas bubbles?

### **Adaptations**

- Ask students to use different shaped containers that represent the magma chamber and conduit of a volcano. How does shape affect the eruption results?
- For younger students, direct them to draw lines on a piece of paper that divide it into six sections. Ask students to draw a before, during, and after experiment picture in squares 1, 2, and 3. Instruct students to draw pictures in squares 4, 5, and 6, of what a volcano would look like if it behaved like the experiment represented in squares 1, 2, and 3 respectively.

### **Extensions**

- Instruct students to make a four-page book that illustrates gas bubbles increasing in size as the magma rises in the Earth and ends with a volcano erupting.
- Search for the link between volcanic gases and acid lakes. Ask students to use the Internet to research this topic. Some examples of acid lakes include Lake Nyos, Cameroon, Kawa Ijen, Indonesia, and Santa Ana, El Salvador.
- Direct students to explore Internet-based computer programs that simulate volcanic eruptions. Note the list of selected computer programs in Internet Resources.

### **Assessment:**

Look for evidence of students' understanding of the following concepts: that magma contains gases under great pressure; that gases provide the energy for volcanic eruptions; that gases influence the texture and appearance of volcanic rocks. Look for student's recognition that of the differences between the baking soda and vinegar eruption which is based on chemical reactions, and an actual volcanic eruption, which is based solely upon pressure release.

## **What Starts an Eruption?**

### **Narrative**

Gases, such as water vapor, CO<sub>2</sub>, SO<sub>2</sub>, and other rarer gases, are the driving forces that power explosive volcanic eruptions. However, gases are not the only players in a volcanic eruption. The size and explosiveness of an eruption are also controlled by the amount of magma in the magma chamber, the magma's mineral composition, and the pressure change in the narrow conduit that leads to Earth's surface.

### **Magma**

Deep below the surface of the earth, the subducting plate's temperature increases. Water rises out of the sinking slab, migrates into the surrounding hotter mantle rock, and initiates melting. The molten rock is called magma.

### **Pressure**

Pressure increases progressively with depth below Earth's surface at a rate of 250 bars per kilometer (400 bars per mile). At sea level, we feel approximately one bar (fourteen pounds per square inch) of pressure from Earth's atmosphere. The pressure from the overlying rock can be 30,000 bars (440,000 pounds per square inch) or more! Steam and other gases dissolve into the magma because of the extreme pressure exerted by overlying and surrounding rocks.

### **Magma Chamber**

The magma chamber is a zone of molten and partially molten rock that exists beneath a volcano. The top of the magma chamber at Mount Rainier is about eight kilometers (five miles) below the Earth's surface and is only a few kilometers wide. As gas bubbles accumulate, the upward pressure increases, forcing cracks in the rocks to widen.

### **Magma Conduit**

With the accumulation and rise of bubbles through the magma chamber, the pressure increases and will eventually become great enough to break through overlying roof rocks, creating a conduit to the surface. Magma escapes through the "super highway" of the volcano, known as the magma conduit or throat. This long, narrow opening leads from the top of the magma chamber to the Earth's surface. The throat of Mount Rainier is only ten to fifteen meters (33 to 50 feet) wide and is currently filled with solid rock.

As gas bubbles rush up the magma conduit, the pressure declines, causing the bubbles to expand rapidly. They can expand to thousands of times their original size! The rapid expansion of gas bubbles propels the magma and gas up the conduit. Within minutes, the volcano erupts, explosively spewing hot lava and tephra into the air. If the magma is "runny enough," the gas bubbles escape easily; and instead of exploding, magma pours down the flanks of volcano as a lava flow.

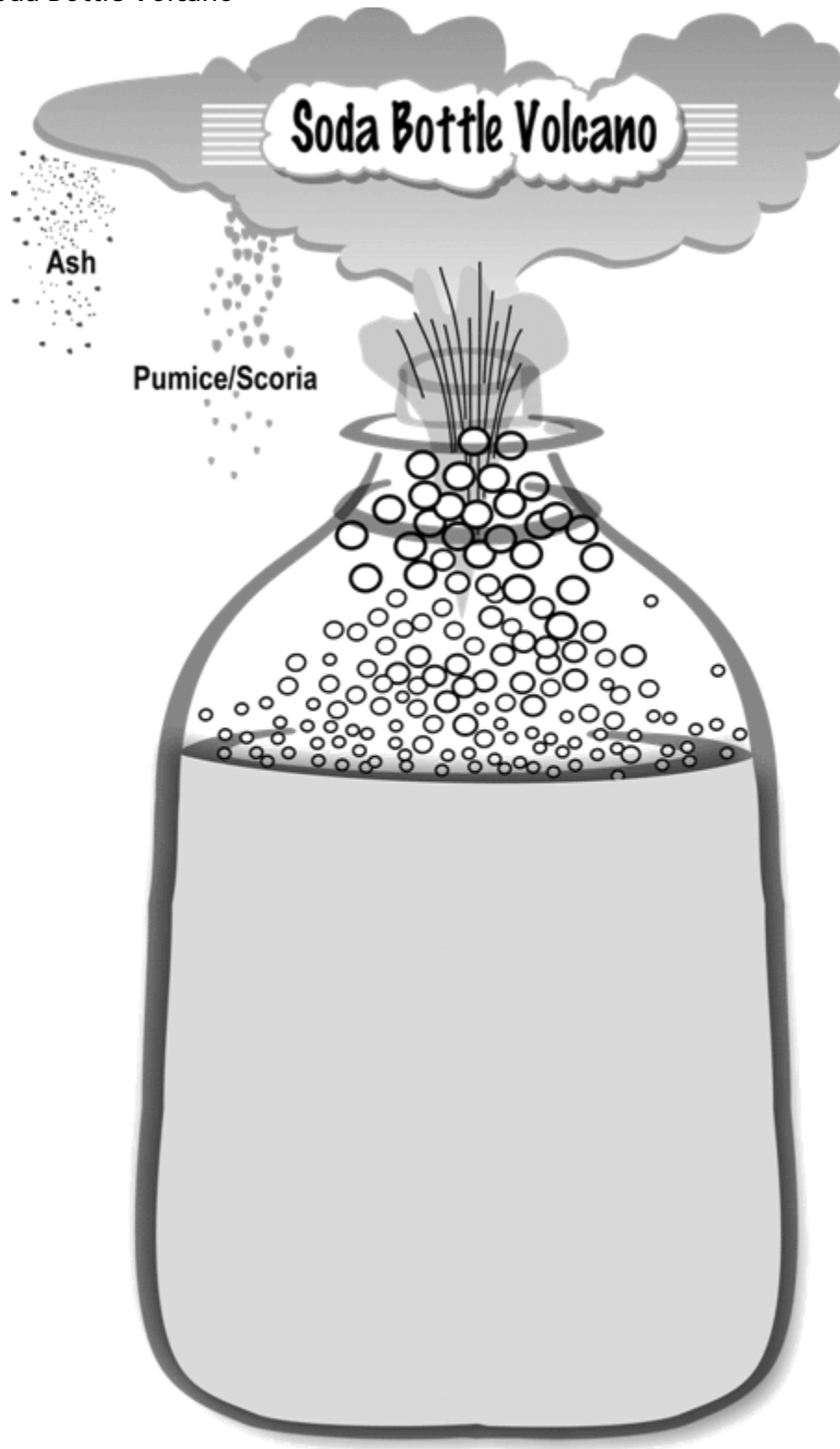
### **Vents and Fumaroles**

Cracks and fractures in the rock can allow gases to escape from the magma. If enough gas escapes, the character of the eruption will be changed from explosive to non-explosive.

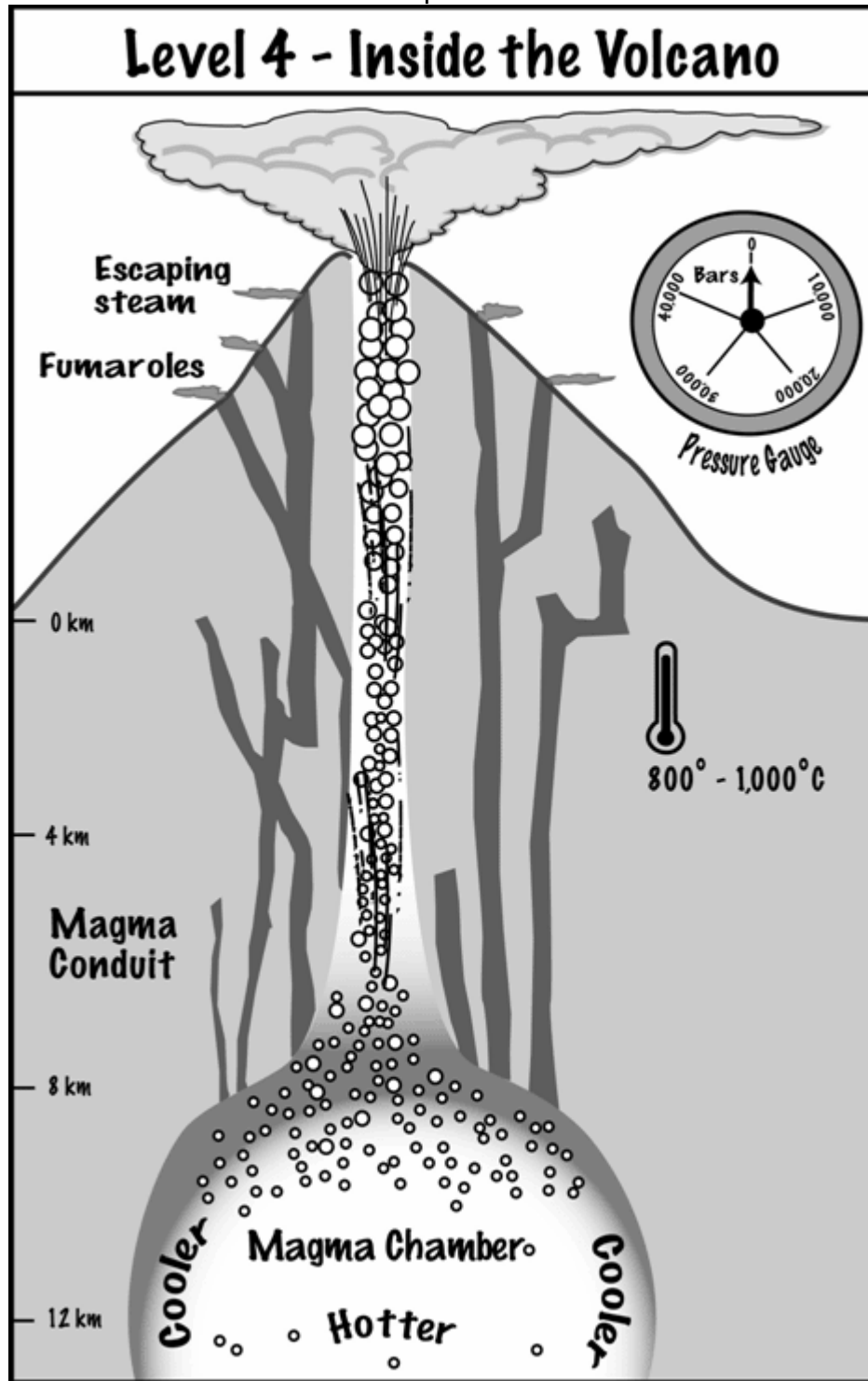
### **References:**

Decker, R. and Decker, B., 1998, *Volcanoes*: W.H. Freeman and Company, New York, 321 pages.  
Francis, P., and Oppenheimer, C., 2003: *Volcanoes*: Oxford University Press, 536 pages.  
VanCleve, Janice, 1994, *Volcanoes—Mind-boggling experiments you can turn into science fair projects*: John Wiley and Sons, New York, 89 p.

Graphic—Soda Bottle Volcano



Graphic—The Role of Gas Bubbles in an Eruption



June 20, 2005